The Fundamentals of Asset Management

Step 6. Determine Business Risk ("Criticality")

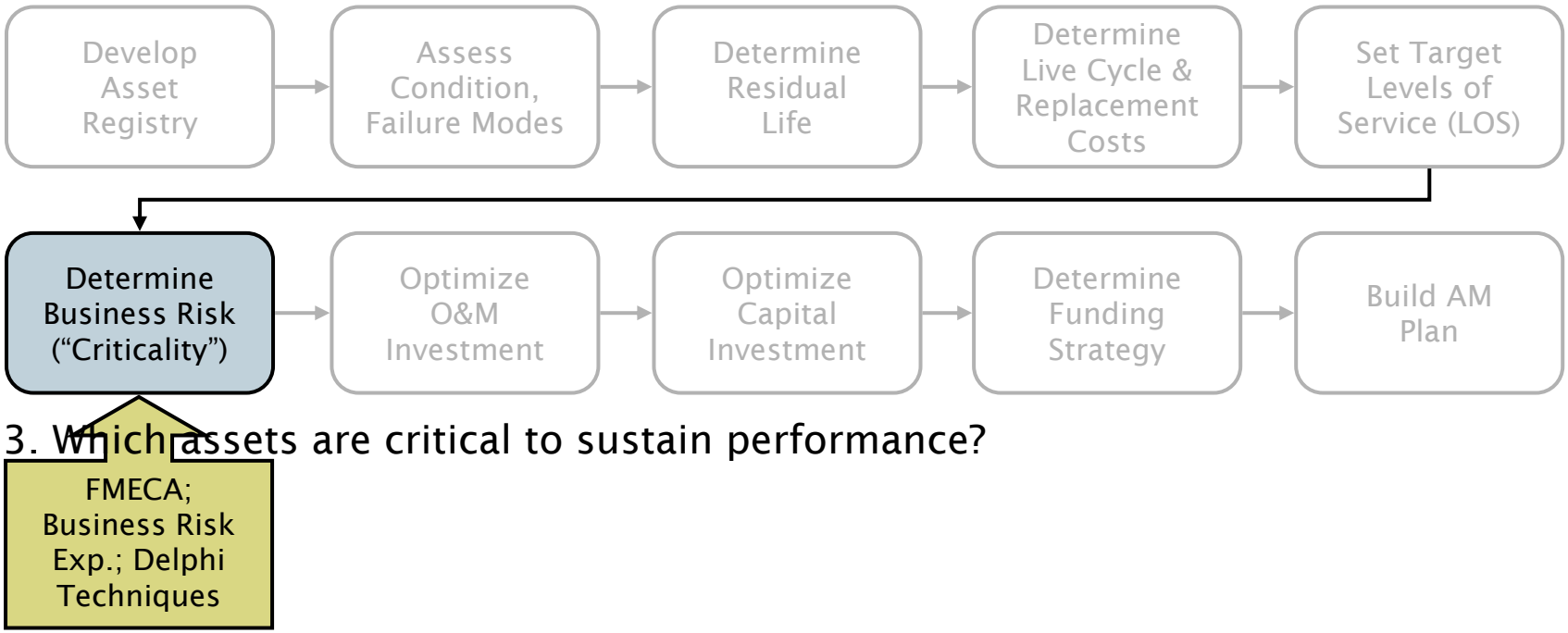
A Hands-On Approach

Tom’s bad day…

Third of 5 core questions

3. Which assets are critical to sustained performance?
   - How *does* it fail? How *can* it fail?
   - What is the *likelihood* of failure?
   - What does it *cost* to repair?
   - What are the *consequences* of failure?

AM plan 10-step process



Risk is the heart of AM

Definition of *risk*

- *Risk* in AM-speak is the *consequence of failure multiplied by the probability of failure*
- Often used as a measure of *"criticality"*
- Preferred term is *"business risk exposure (BRE)"*

Variables in *business risk exposure*

- *Probability* or likelihood of failure (PoF)
- *Consequence* or impact of failure (CoF)

Let’s clarify terms

Ambiguous:

- “Risk”
- “Criticality”

Preferred:

- Probability of failure
- Consequence of failure
- *“Business risk exposure”*

All assets have a probability of failure

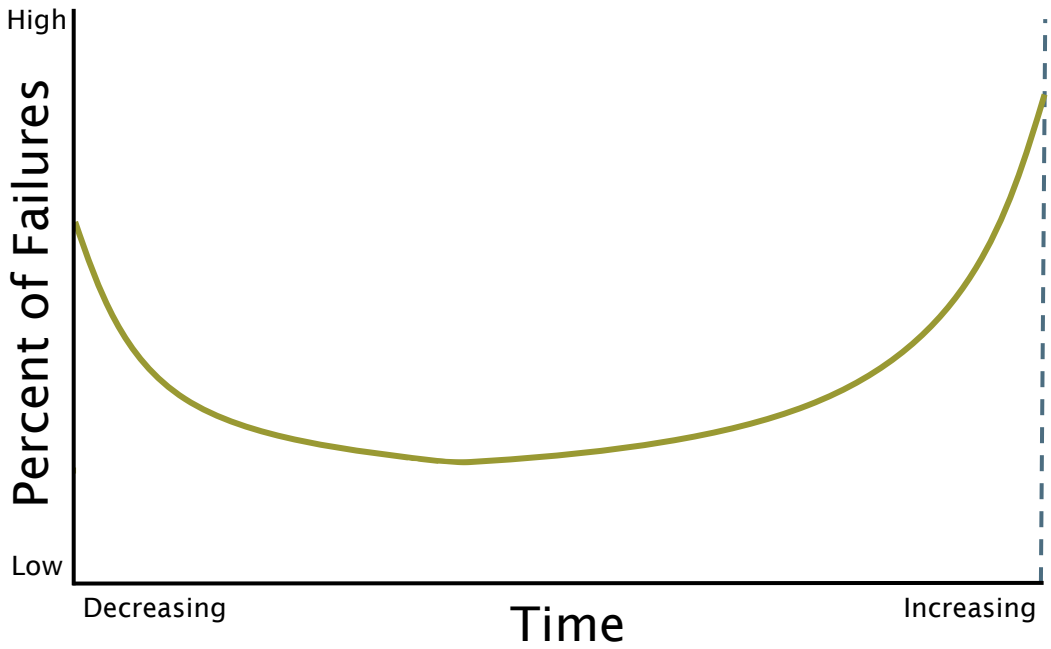
Two key questions…

1. Is the failure reasonably *predictable*?
2. Is it cost-effectively *preventable*?

Most common patterns of failures

Two key failure patterns

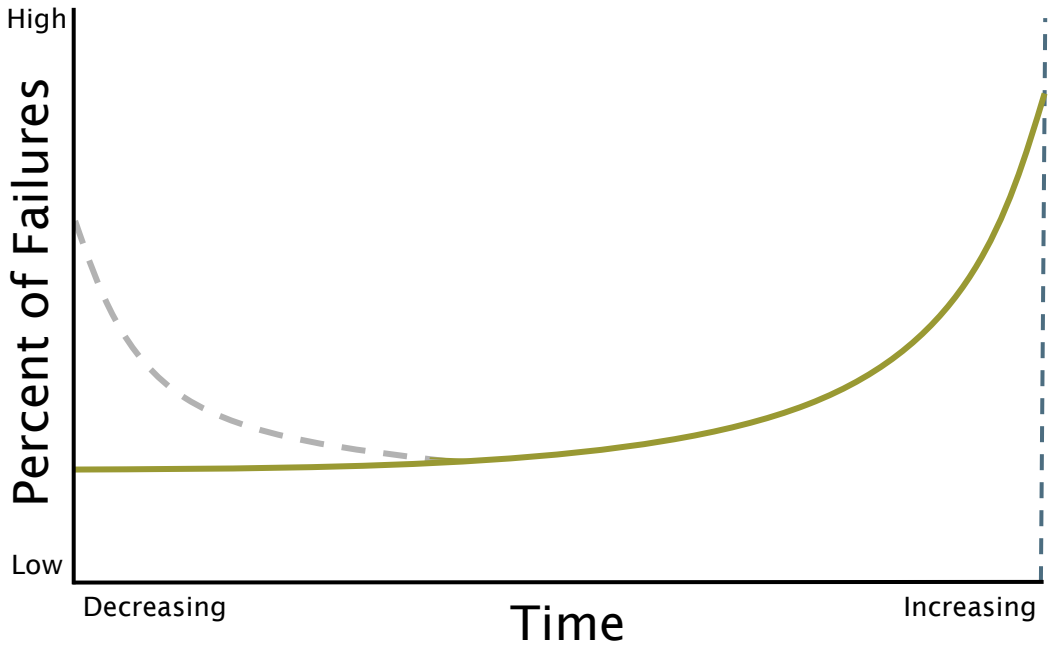
1. *Bathtub curve*—typically applicable for mechanical and electrical assets



Most common patterns of failures

Two key failure patterns

1. *Bathtub curve*—typically applicable for mechanical and electrical assets
2. *Age-based curve*—typically applicable for civil passive assets



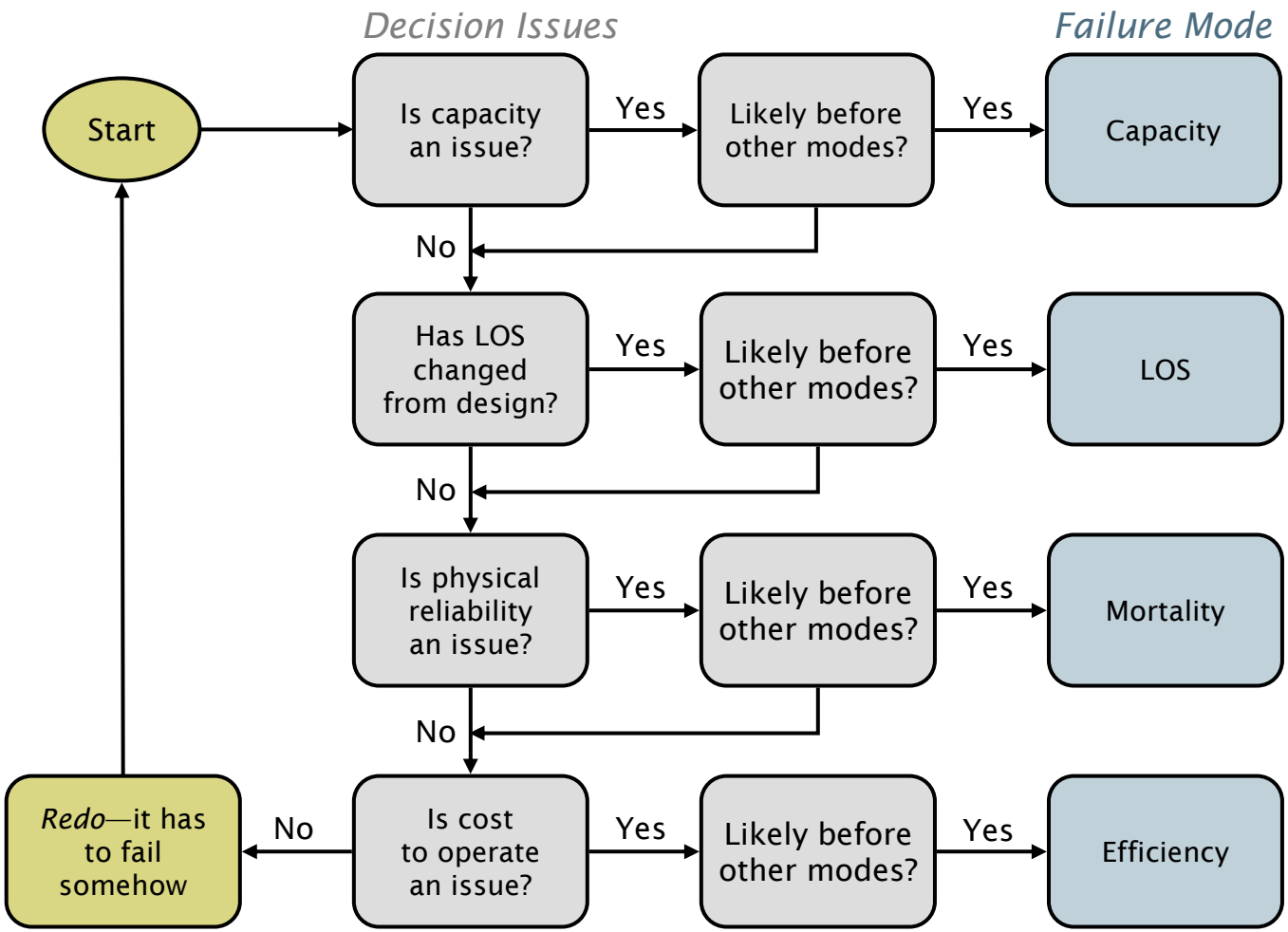
Reliability—the probability that a component or system will perform its specified function for the specified period under specified operation conditions

Recall the four major *failure modes*

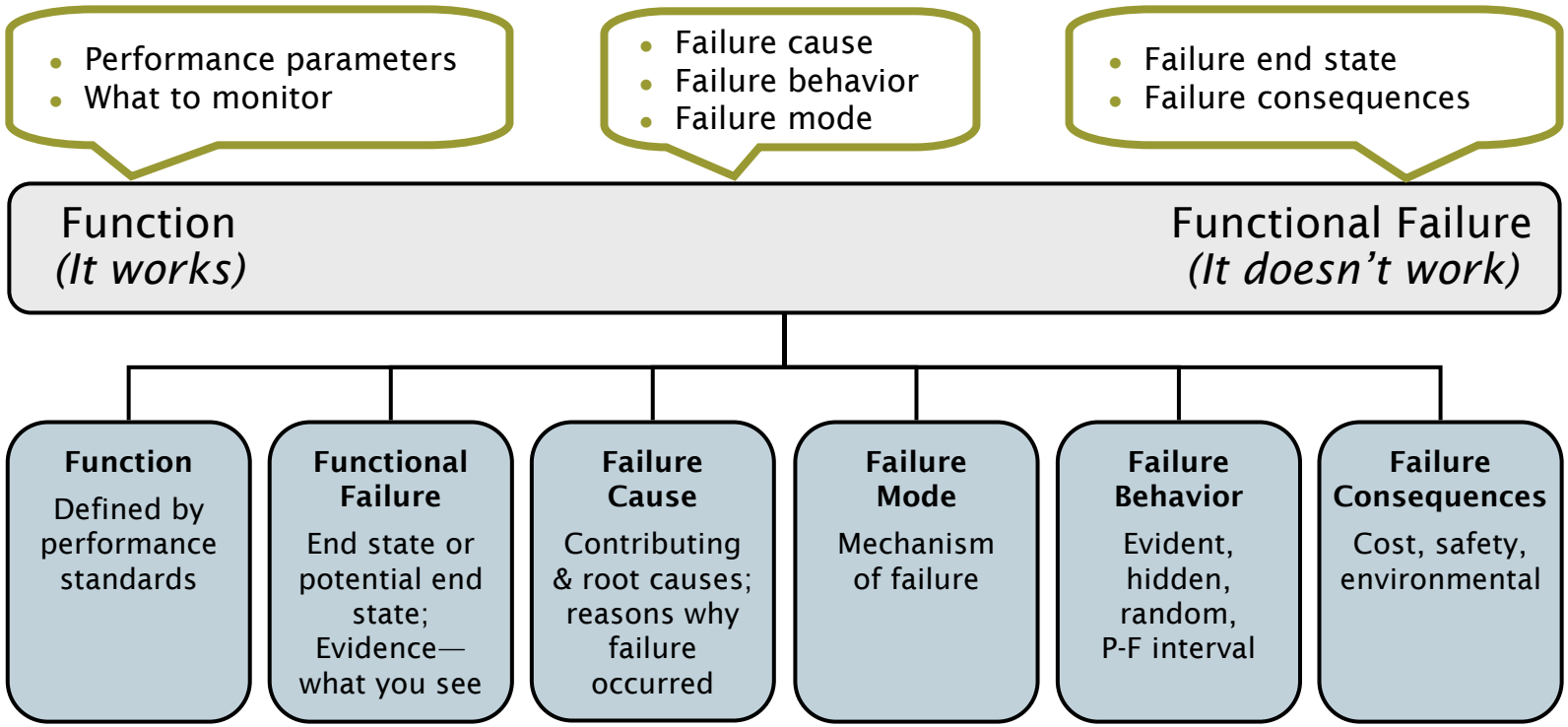
Failure Mode	*Definition*	*Tactical Aspects*	*Management Strategy*
Capacity	Volume of demand exceeds design capacity	Growth, system expansion	Redesign
LOS	Functional requirements exceed design capacity	Codes & permits: NPDES, CSOs, OSHA, noise, odor, life safety; service, etc.	O&M optimization, renewal
Mortality	Consumption of asset reduces performance below acceptable level	Physical deterioration due to age, usage (including operator error), acts of nature	O&M optimization, renewal
Efficiency	Operations costs exceed that of feasible alternatives	Pay-back period	Replace

NPDES is National Pollutant Discharge Elimination System, CSOs are combined sewer overflows, and OSHA is Occupational Safety and Health Administration

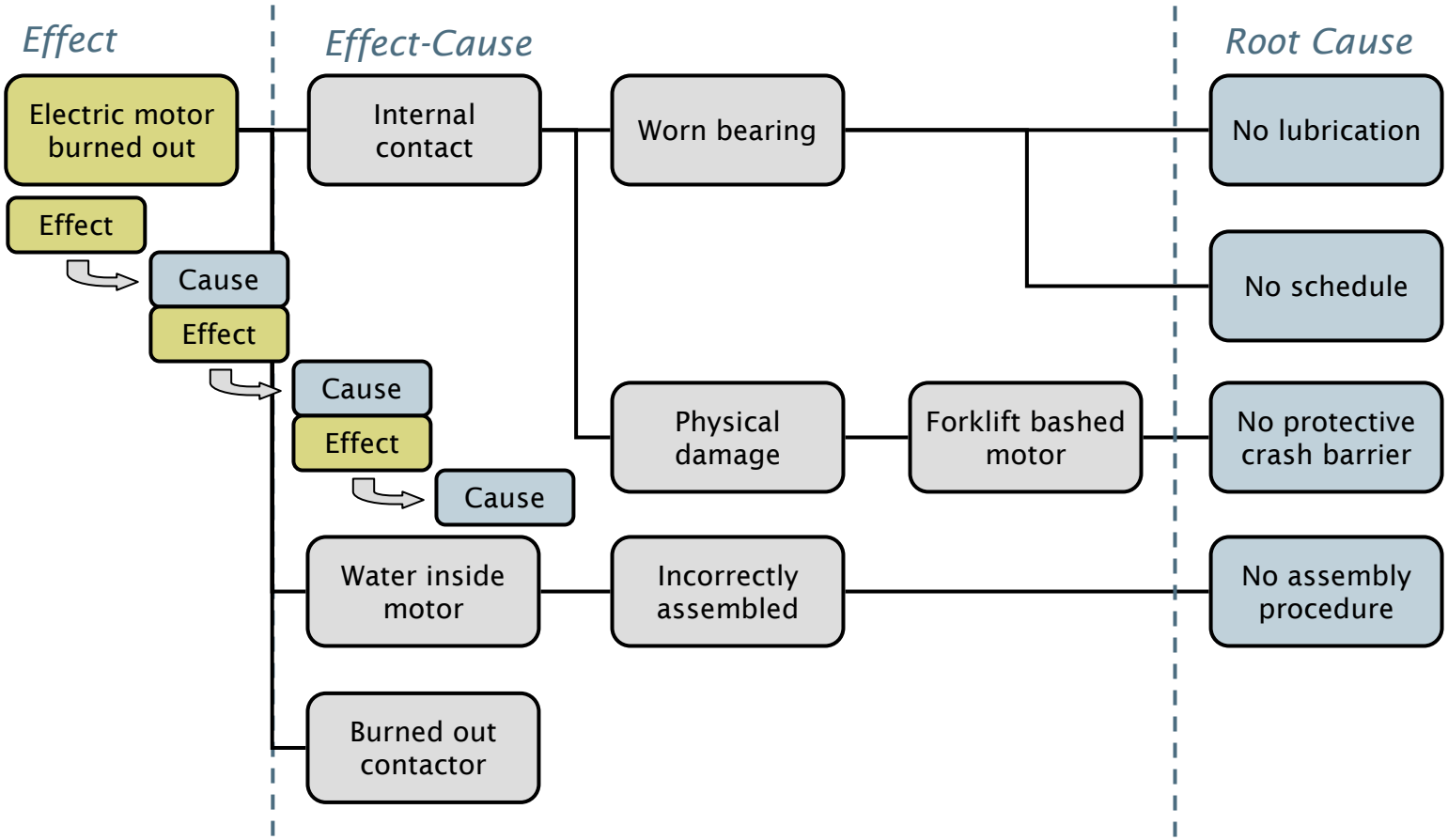
Using failure modes to determine probability of failure



Failure analysis



Cause and effect diagram



Probability of failure (PoF)

- PoF is directly related to the *failure mode*
- We *cannot* absolutely determine PoF
- Sometimes we have good data, sometimes we do not
- We can estimate a *range of failure*—how early (pessimistic) and how late (optimistic)

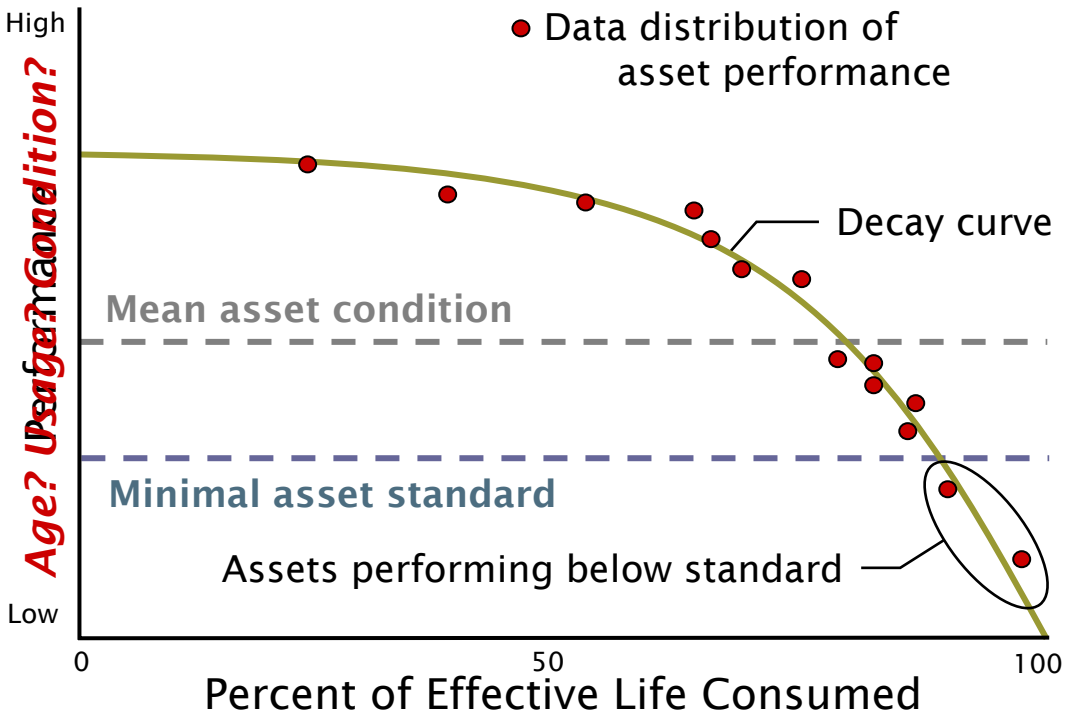
What are sources of Probability of Failure?

- CMMS—*mean time between failures* (MTBF)
- Vendor and industry information
- Other *failure records* (hard copies)
- Our brilliant *memories* (staff)
- Our *SCADA system* (if we have one and if it keeps records on this asset)

PoF is probability of failure, CMMS is computerized maintenance management system, SCADA is supervisory control and data acquisition

Finding a *proxy* for measuring failure

Can *age*, *usage*, or *condition* be substituted?...



Linking probability of failure to age of asset

% of Effective Life Consumed	*PoF Rating*
0	1
10	2
20	3
30	4
40	5
50	6
60	7
70	8
80	9
90	10

PoF is probability of failure

Linking probability of failure to condition

	Condition Rating & Residual Life Factor									
Asset Type	***1***	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***10***
Civil	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1	0
Pressure pipework	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1	0
Sewers	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1	0
Pumps	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1	0
Valves	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1	0
Motors	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1	0
Electrical	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1	0
Controls	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1	0
Building assets	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1	0
Land	1	1	1	1	1	1	1	1	1	1

Linking probability of failure to direct observation tables

*Assessment **	*Probability Weighting*	*Description*
Almost certain	100	Expected to occur within a year
Very high	75	Likely to occur within a year
High	50	Estimated 50% chance of occurring in any year
Quite likely	20	Expected to occur within 5 years Estimated 20% chance of occurring in any year
Moderate	10	Expected to occur within 10 years Estimated 10% chance of occurring in any year
Low	2	Expected to occur within 50 years
Very low	1	Expected to occur within 100 years

***** Likelihood of occurrence within a year

Scoring Probability of Failure

Probability of Failure						
Performance: Capacity, Efficiency, LOS/Regulation	Exceeds Current & Future Expectations	Meets Current Expectations	Room for Improvement	Obvious Concerns; Cost/Benefit Questions	Bottleneck; Inefficient; Obsolete	Failing; Not Up To Industry Standards or Technology
Mortality: Repair History	No Reason to Suspect Problems	Some Repairs Rqd As Expected	Suspect Above Ave Problems	Reputation As Lemon	Repair is Excessive or Not Worth It	Resource Intensive Other Work Neglected
Mortality: Equipment Life	Asset is Almost New	30% Consumed	45% Consumed	60% Consumed	85% Consumed	End of Life or in Failure
Maint. Practice: Monitoring & Prevention	Above Normal Intervention Not Beneficial	Maint & Monitoring is Adequate	Some Done But Need More	Needs Not Met Most of the Time	Substantial Care Rqd But Not Done	Imminent Failure; No Action; Dereliction of Duty;
Asset Alignment to Mission & General Outlook	Failure is Rare (>20yrs)	Failure Unlikely (10-20yrs)	Failure Possible (6-10yrs)	Moderate Chance (3-5yrs)	Failure Likely (2yrs)	Failure Almost Certain (1yr)
Score A	1	3	5	7	9	10

Quantifying *consequence of failure*

Simple

Consequence of Failure		
CoF Rating	**Description**	**%**
1	Minor Component Failure	
2	Major Component Failure	
3	Major Asset	
4	Multiple Asset Failure	
5	Major Facilty Failure	
6	Minor Sanitory System Failure	
7	Medium	
8	Intermediate	
9	Significant	
10	Total	

Sophisticated

- **Direct Costs to the Local Government**
  - Repair and return to service costs
  - Service outage mitigation costs
  - Utility emergency response costs
  - Public safety costs
  - Admin & legal costs of damage settlements
  - (Lost product costs)
- **Direct Customer Costs**
  - Property damage costs (including restoration of business)
  - Service outage costs
  - Service outage mitigation and substitution costs
  - Access impairment and travel delay costs
  - Health damages
- **Community Costs**
  - Emotional strain/welfare
  - Environmental Pollution, erosion, sedimentation
  - Destruction of/damage to habitat
  - “Attractability” (tourist, economic)

Scoring the Consequence of Failure

Consequence of Failure						
Spill, Flood, Odor	Short Duration Sm. Qty. Onsite: No complaints	Backups; Small No. of Complaints	Aggressive complaints and liability	Substantial Liability Many Impacted	Has not Happened at this Scale Before	Sustained, Lg. Qty. Offsite Many Complaints
Process & Effluent Quality	No impact: SS; BOD; MPN; Cake	Routine Adjustment	Significant Corrective Action	Significant Adj. With Uncertainty	Major Process Recovery with Lag Time and Uncertainty	Loss of Process Control
Environmental and Permit	No Consequence	Violated Daily Standard	Violated Weekly Standard	Violated Monthly Standard	Damage Reversible in Six Months	Permit Jeopardized; Damage Reversible in 5 yrs
ECDEP Image	No Media or No Consequence	Neutral Coverage	Adverse Media	Widely Adverse Media	Continual; Political Opposition	National Adverse Media
Hassle Factor & Economics	Low Cost & low Hassle	Low Cost & High Hassle	High Cost; Low Hassle	High Cost & High Hassle & Diverts $	Painful Change of Priorities	May Prompt Rate Increase; Staff Changes
Loss of Service Impacts	Can be out of service indefinitely	Cannot be down a month	Cannot be down a week	Cannot be down 1 day	Cannot be down 8 hours	Cannot be down 1 hour
Equipment & Safety	No impact	Part Level; Routine	Asset Level; Minor	Function Level; Major	System Level; Sever	Plant Level; Catastrophic
Score B	1	3	5	7	9	10

Alternative view of *"criticality"*—impact on process

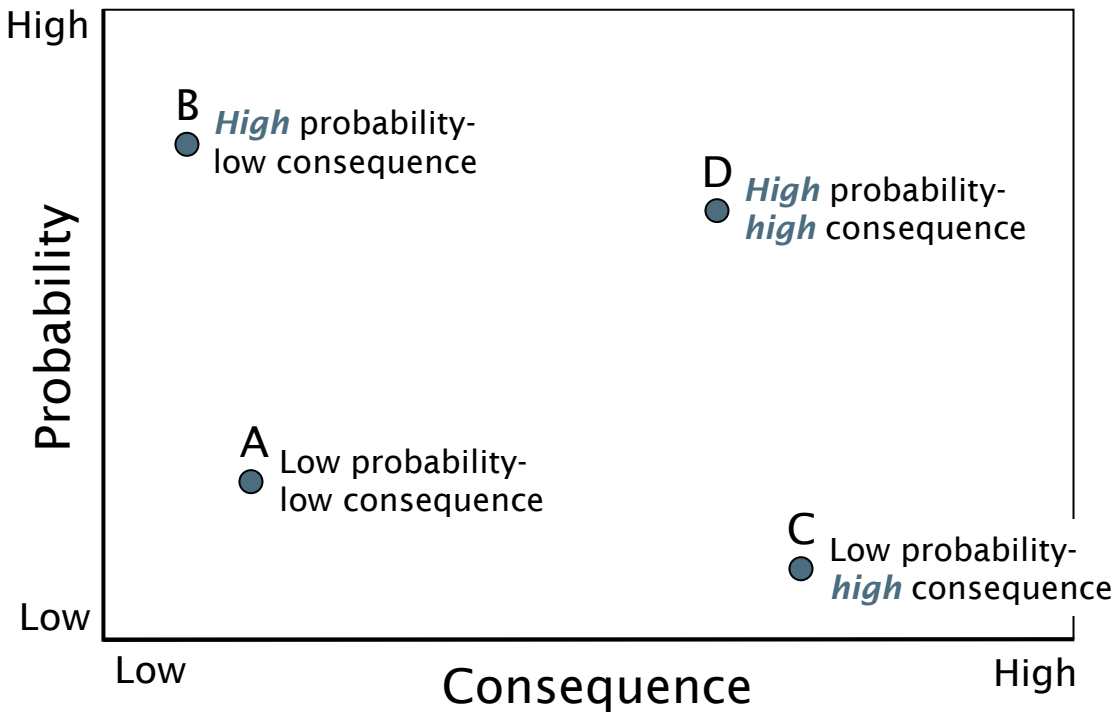
Code	*Description*
1	Mandated by law or corporate policy
2	Impacts multiple processes, runs continuous without an on-line spare
3	Impacts multiple processes, runs intermittently without an on-line spare, and/or causes lost production in fewer than 4 hours
4	Impacts a single process, runs intermittently without an on-line spare, and/or causes lost production between 4-24 hours
5	Impacts a single process, runs intermittently without an on-line spare, and/or causes lost production in fewer than 24 hours
6	Impacts multiple processes, runs continuous with an on-line spare, and causes no lost production
7	Impacts multiple processes, runs intermittently with an on-line spare, and causes no lost production
8	Impacts a single process, runs intermittently or continuous with an on-line spare, and causes no lost production
9	Minor or no impact on safety, product, or cost

Alternative view of *"criticality"*—impact on revenue

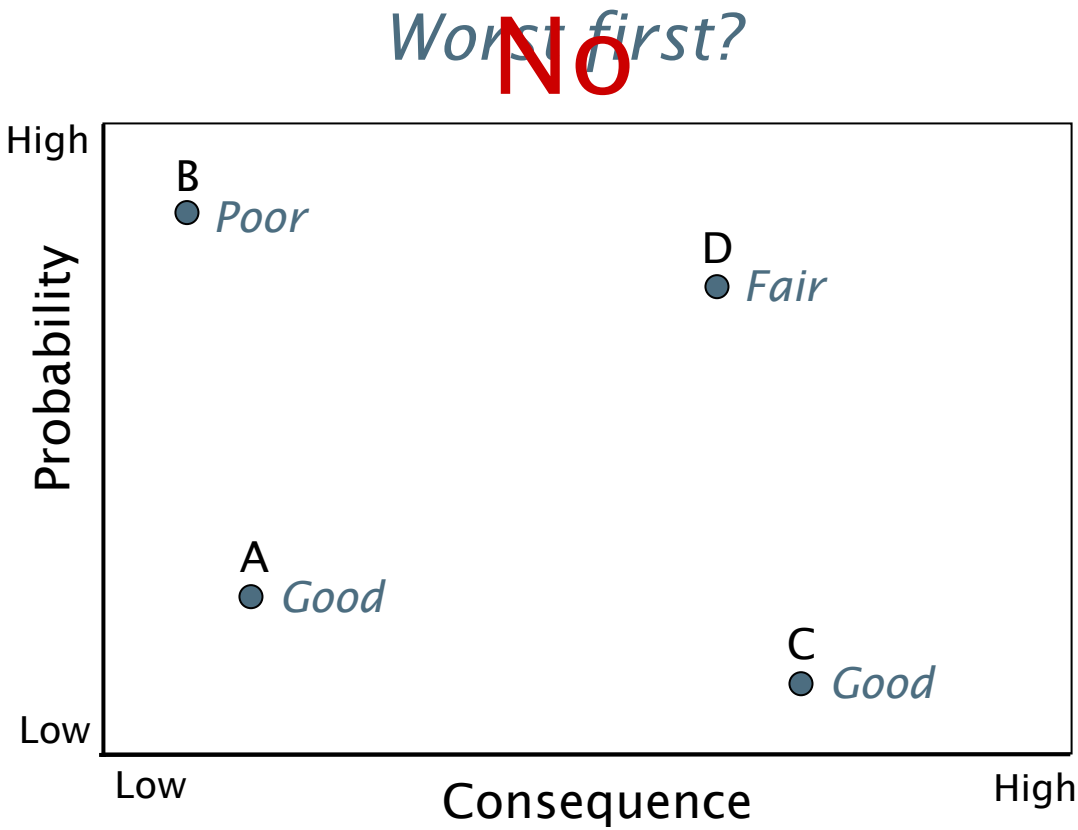
Code	*Description*
1	Assets required for conducting *value stream* functions that produce the core *unit of value*
2	Assets required to ensure that *revenue producing* assets are powered or controlled
3	Assets required for order fulfillment functions such as sales orders, production planning, shipping, and accounting
4	Assets required for other core production or service functions such as material handling or warehousing
5	Non-revenue producing assets required for protecting revenue-producing assets from inoperable conditions
6	Non-revenue producing assets required for conducting supporting business functions
7	Non-revenue producing assets that impact quality of life

Determining significant failures

The business risk exposure trade-off…

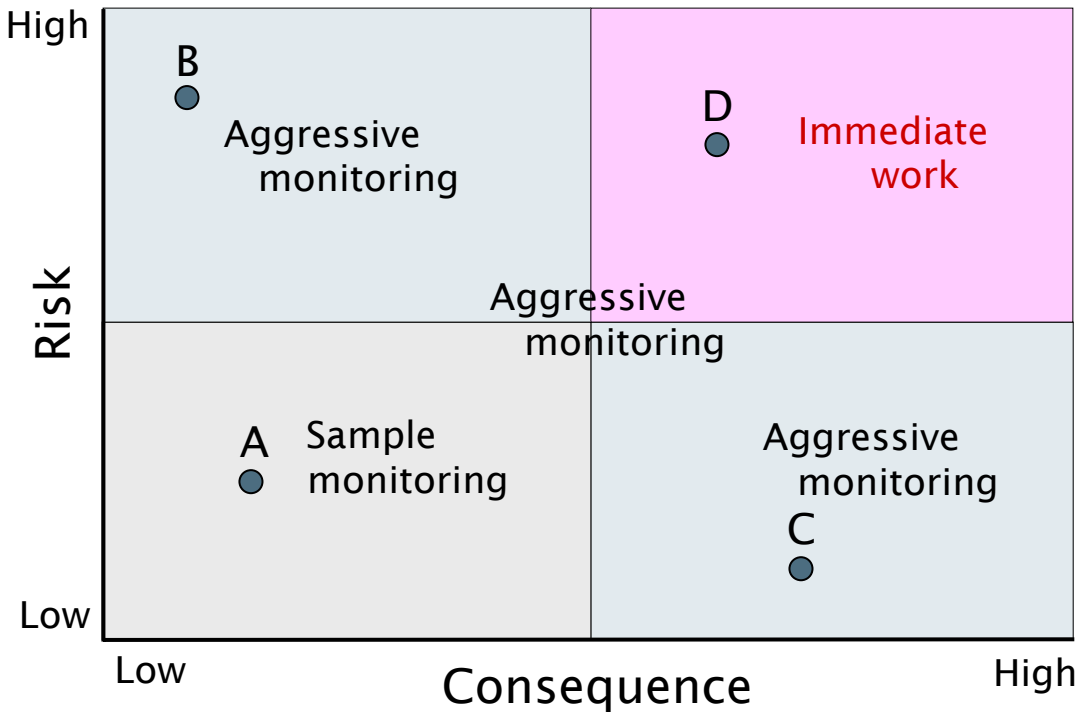


Business risk exposure drives work program



Business risk exposure drives work program

Work program response

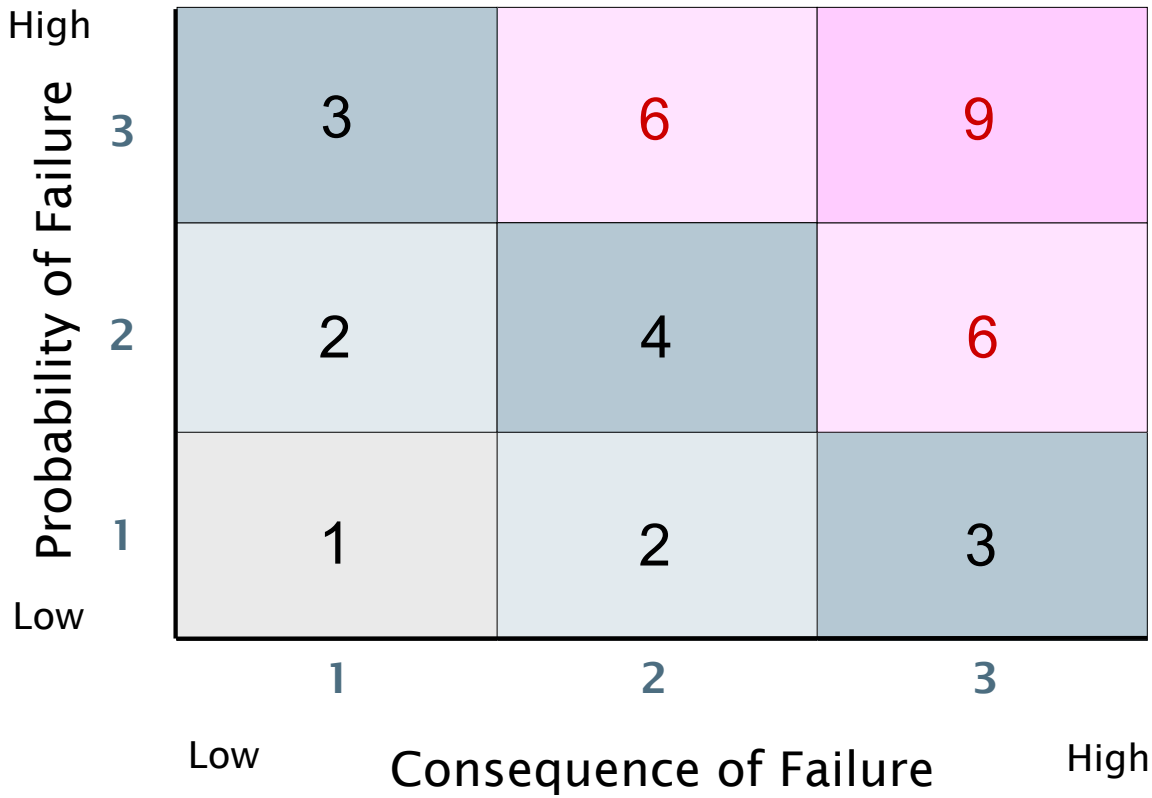


Risk (criticality) metric

PoF x CoF = BRE

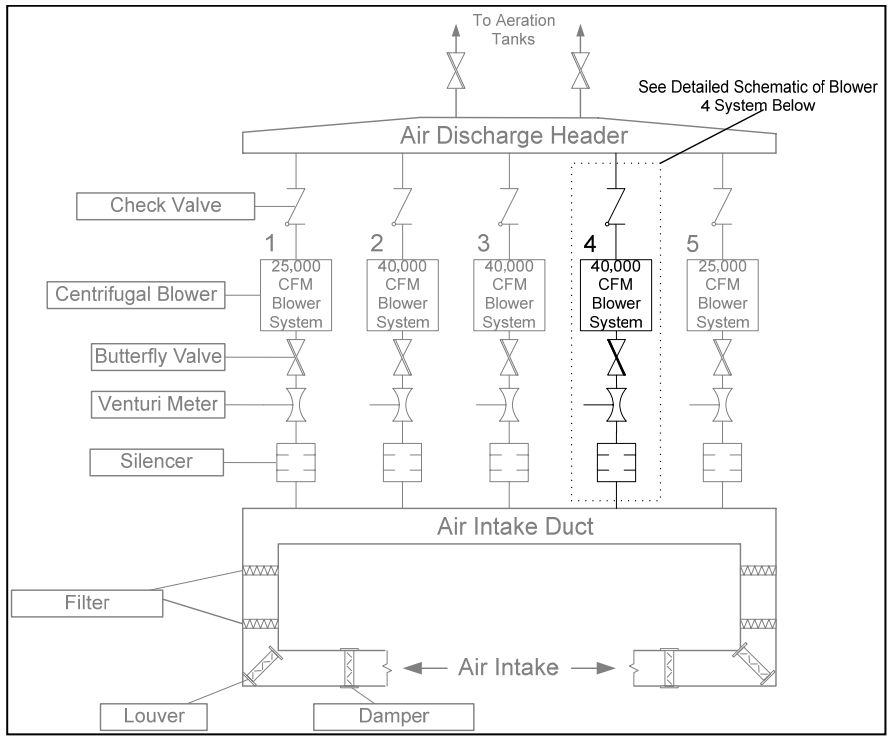
BRE 1—simple approach

Business risk exposure (BRE) increases (higher numbers) as probability of failure (PoF) and consequence of failure (CoF) increase

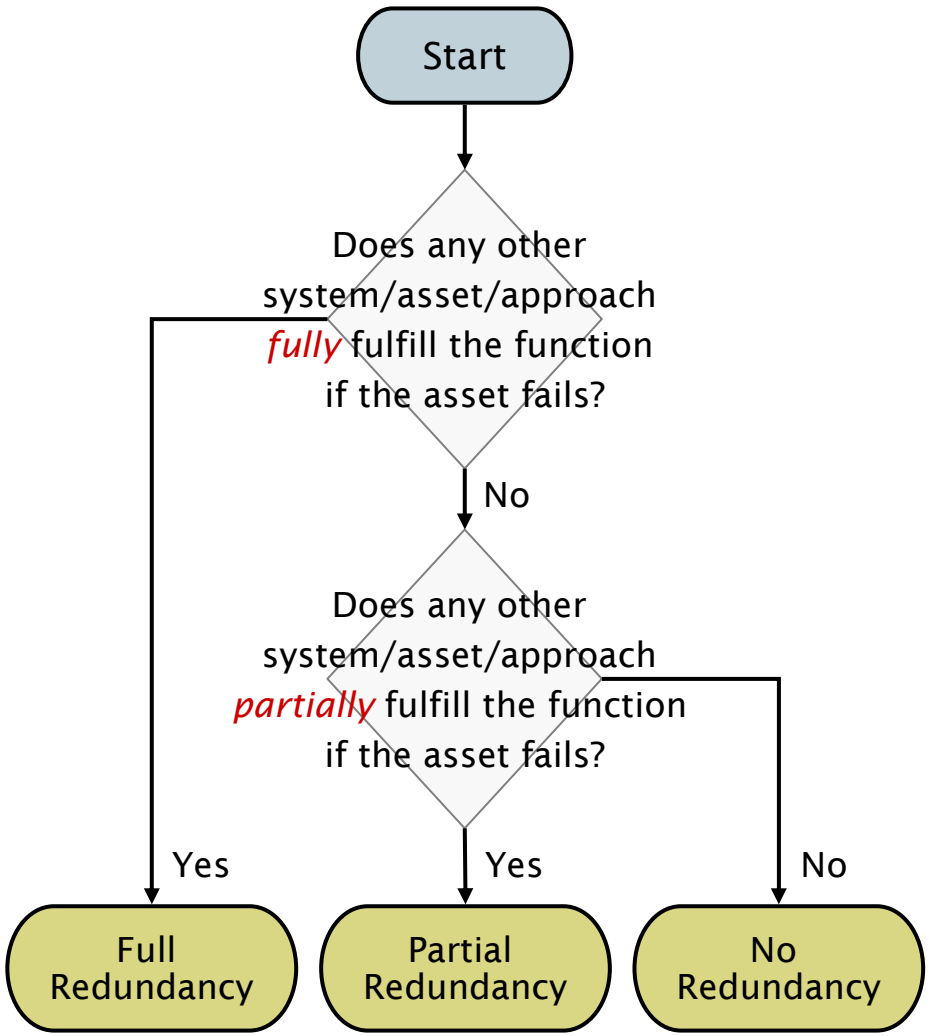


Impact of redundancy on the risk metric

- *Redundancy* significantly reduces the risk metric
- Risk = PoF x CoF *x R*
- Where
  - PoF is probability of failure
  - CoF is consequence of failure
  - R is *redundancy factor*



Determining redundancy



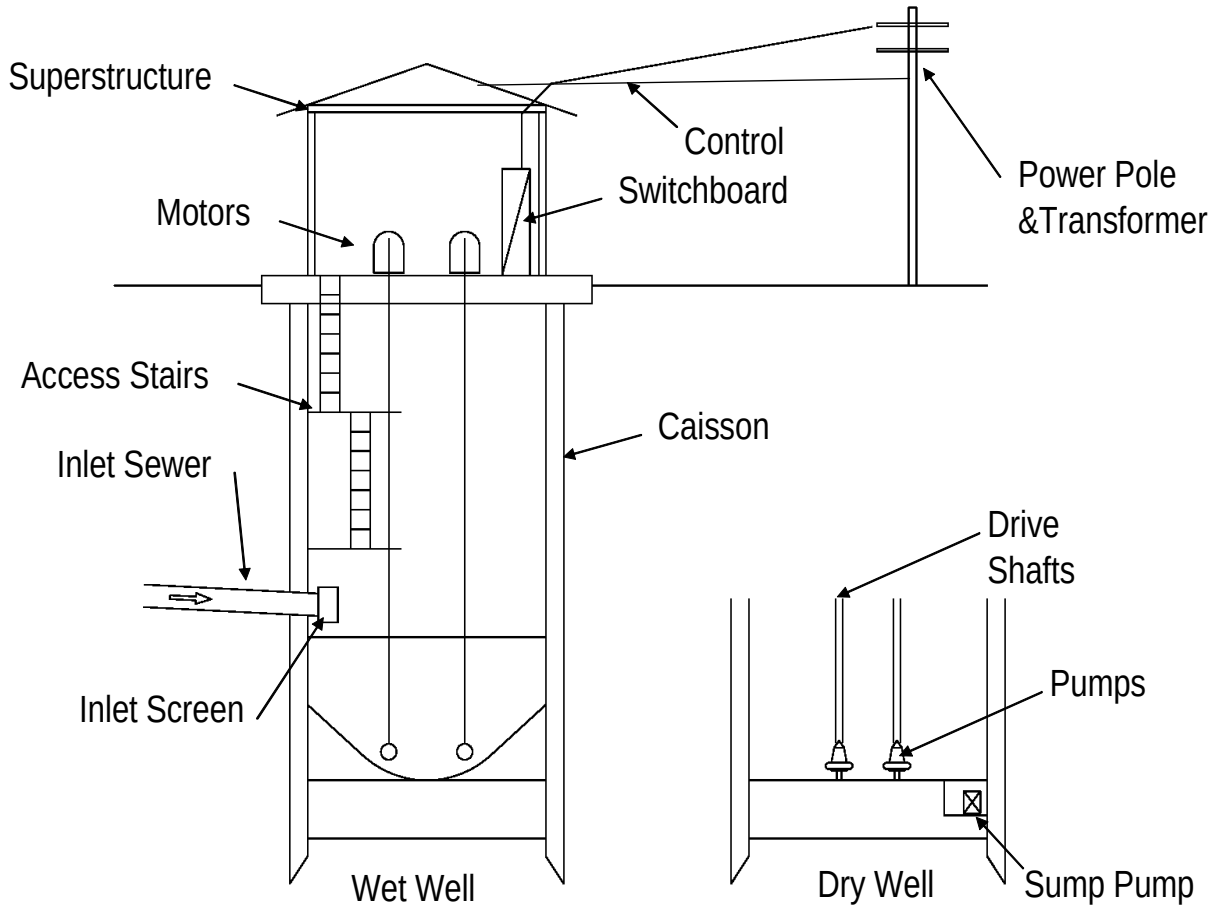
Example of assigning weight to redundancy

Type Redundancy	*Percent Redundancy*	*Percent PoF Reduction*
Partial	50	50
Full	100	90
Double	200	98

Set weights considering operating circumstances, where possible

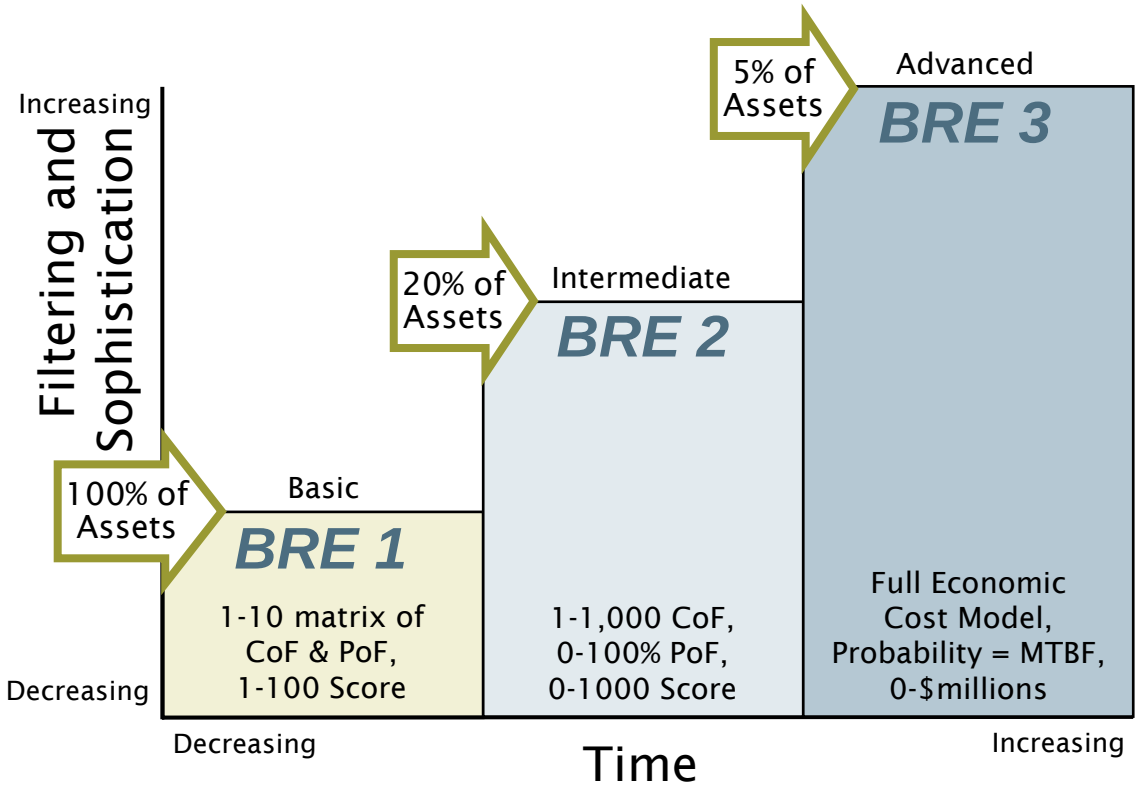
- *True redundancy* (peak vs. average)
- Age and condition of equipment
- Nature of operating environment
- Nature of failure modes (evident, hidden, random)

Does Tom have redundancy? If so, how much?



Step-by-step BRE methodology

Levels of filtering and sophistication



BRE is business risk exposure, CoF is consequence of failure, PoF is probability of failure, MTBF is mean time between failures

Level 1—simple

Risk rating = probability x consequence

Asset No.	*% Probability*	*Consequence*	*Risk Rating*
1	60	4	2.4
2	70	2	1.4
3	40	5	2.0
4	68	10	6.8*
5	95	7	6.7*
6	10	10	1.0

* Requires further investigation

Level 2—intermediate

Multiple elements, enhanced FMECA analysis techniques

Element	*Rating*	*Weighting*	*Max. Score*
Safety	1-5	10	50
Environment	1-5	6	30
Functionality	1-5	5	25
Cost	1-5	8	40
			145

FMECA is failure mode effect critical analysis

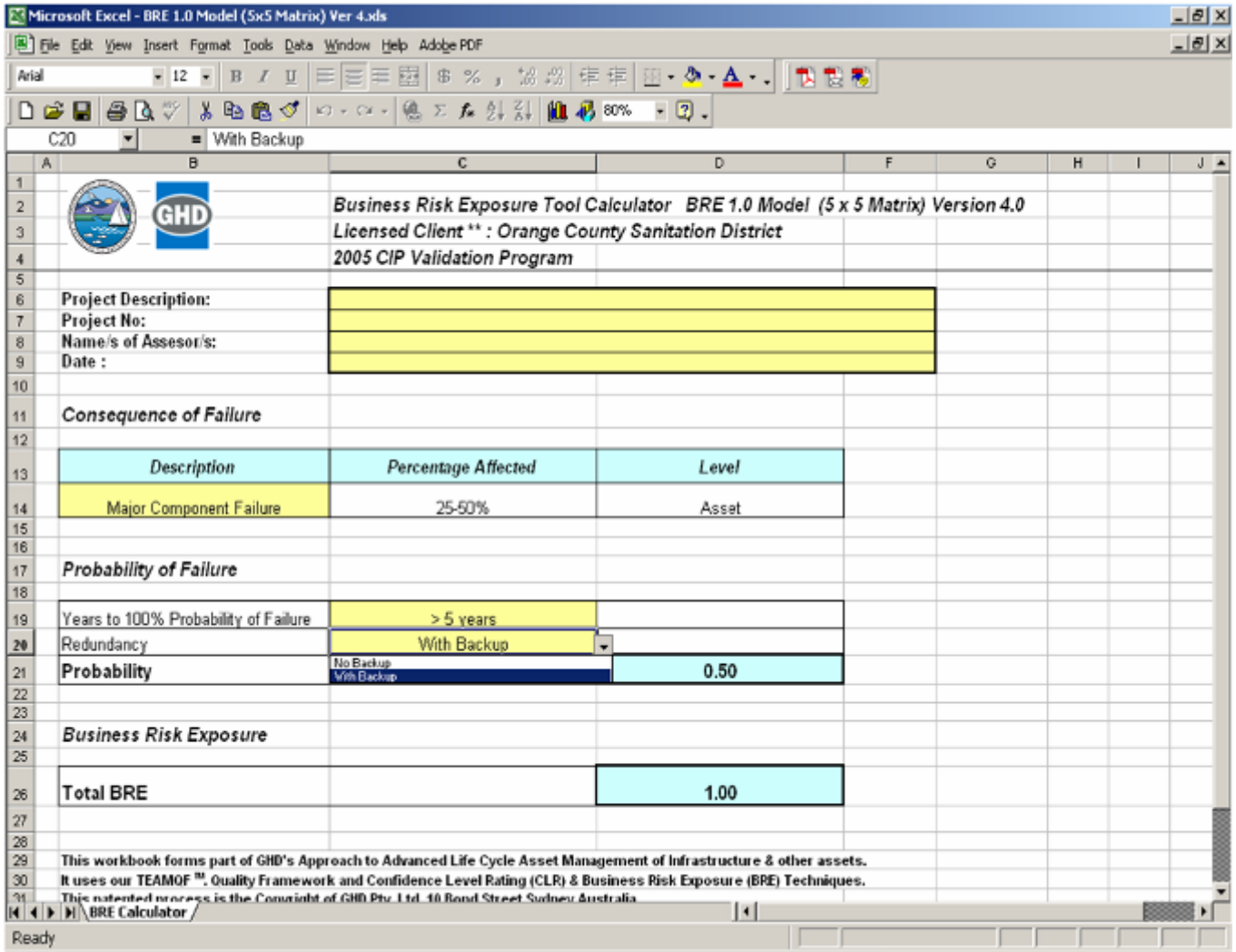
Example of risk table

Matrix of probability and consequence of failure

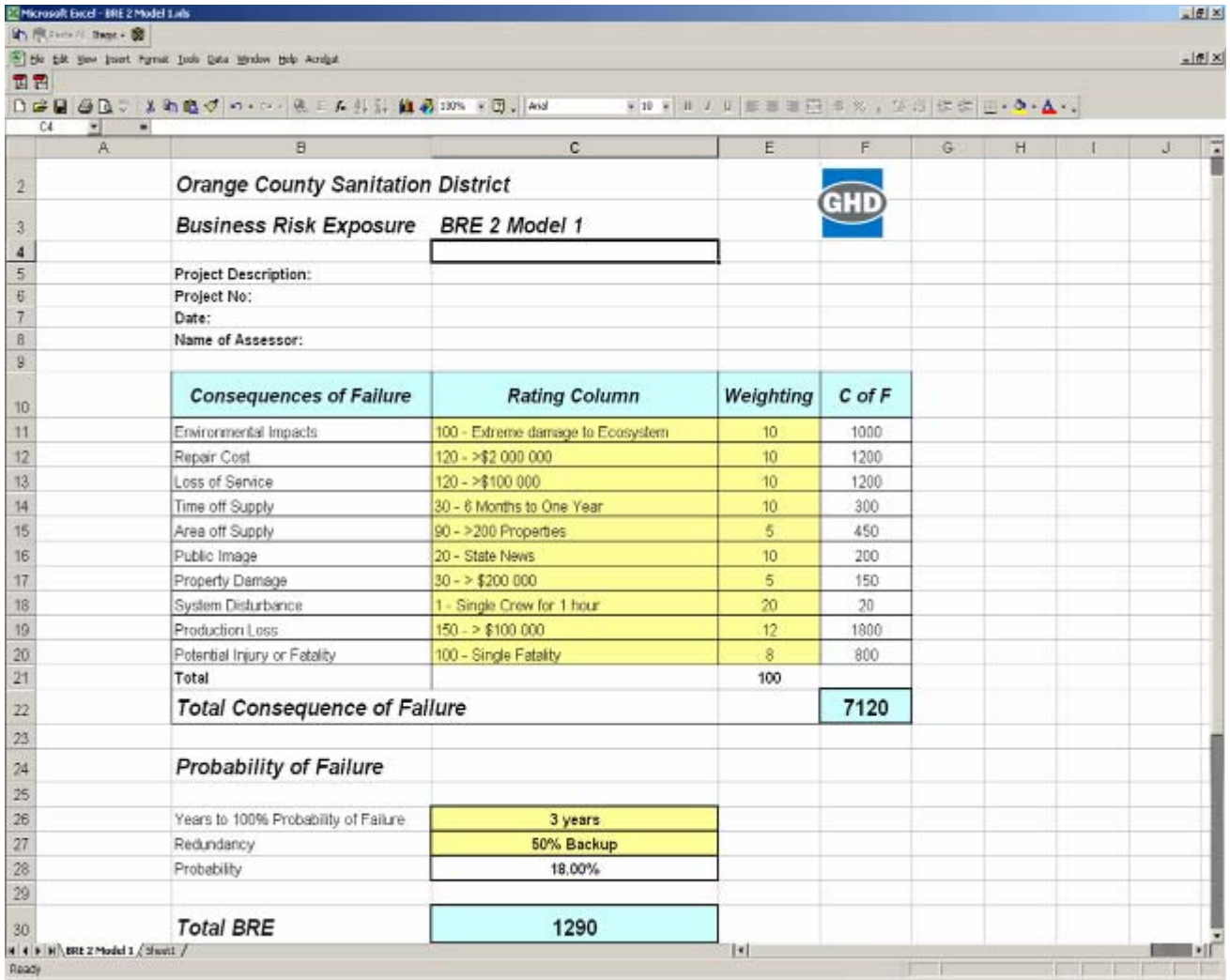
Probability of Failure	*Consequence of Failure*					
	1	*2*	*3*	*4*	*5*	*6*
Very low	L	L	L	L	M	M
Low	L	L	L	M	M	S
Moderate	L	L	M	M	S	S
Quite likely	L	M	M	S	S	H
High	M	M	S	S	H	H
Very high	M	S	S	H	H	H
Almost certain	S	S	H	H	H	H

L is low risk, M is moderate risk, S is satisfactory risk, H is high risk

Example of BRE level 1



Example of BRE level 2



Orange County Sanitation District

Business Risk Exposure **BRE 2 Model 1**

Project Description:
Project No:
Date:
Name of Assessor:

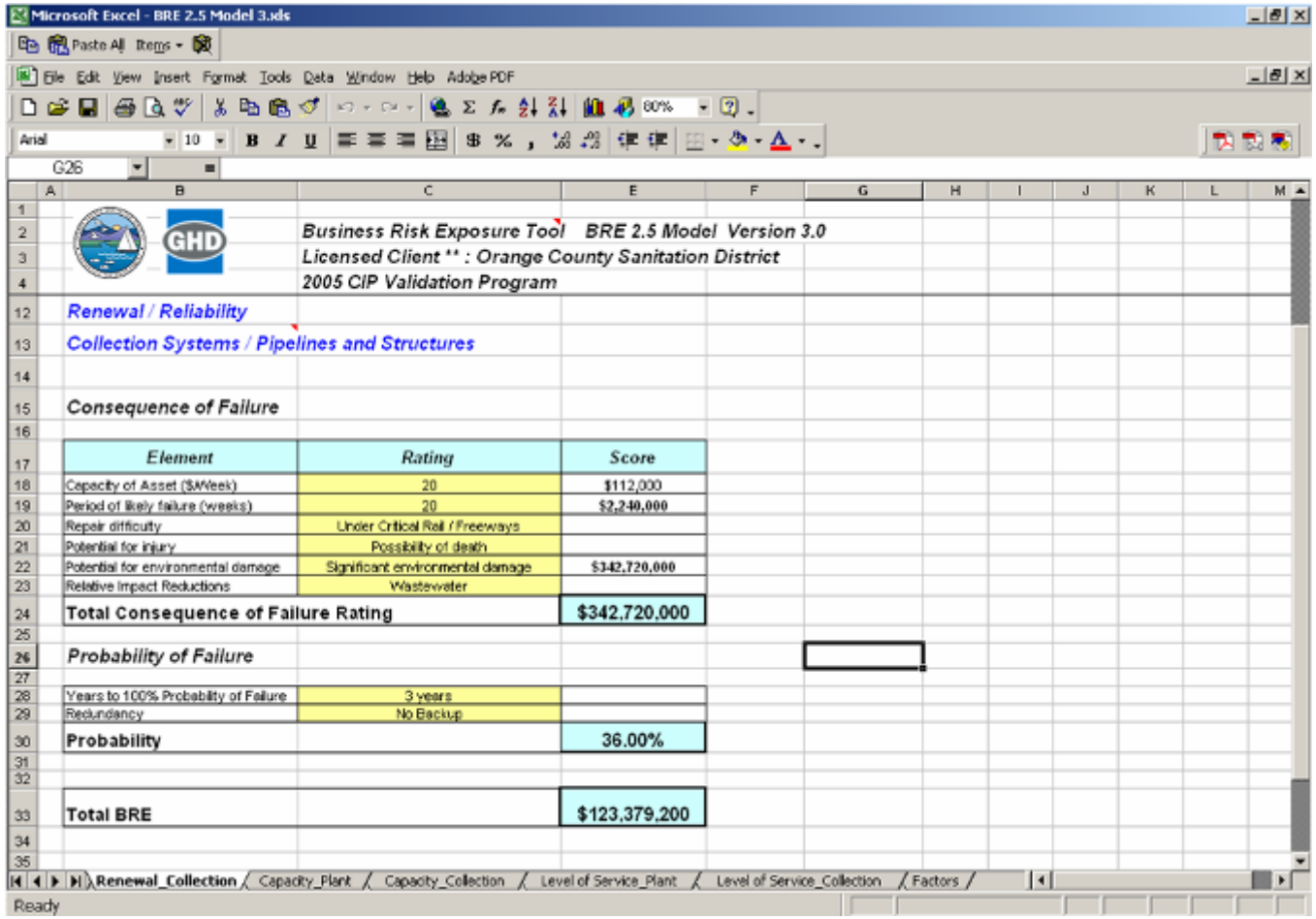
Consequences of Failure	Rating Column	Weighting	C of F
Environmental Impacts	100 - Extreme damage to Ecosystem	10	1000
Repair Cost	120 - >$2 000 000	10	1200
Loss of Service	120 - >$100 000	10	1200
Time off Supply	30 - 6 Months to One Year	10	300
Area off Supply	90 - >200 Properties	5	450
Public Image	20 - State News	10	200
Property Damage	30 - > $200 000	5	150
System Disturbance	1 - Single Crew for 1 hour	20	20
Production Loss	150 - > $100 000	12	1800
Potential Injury or Fatality	100 - Single Fatality	8	800
Total		100	
Total Consequence of Failure			**7120**

Probability of Failure

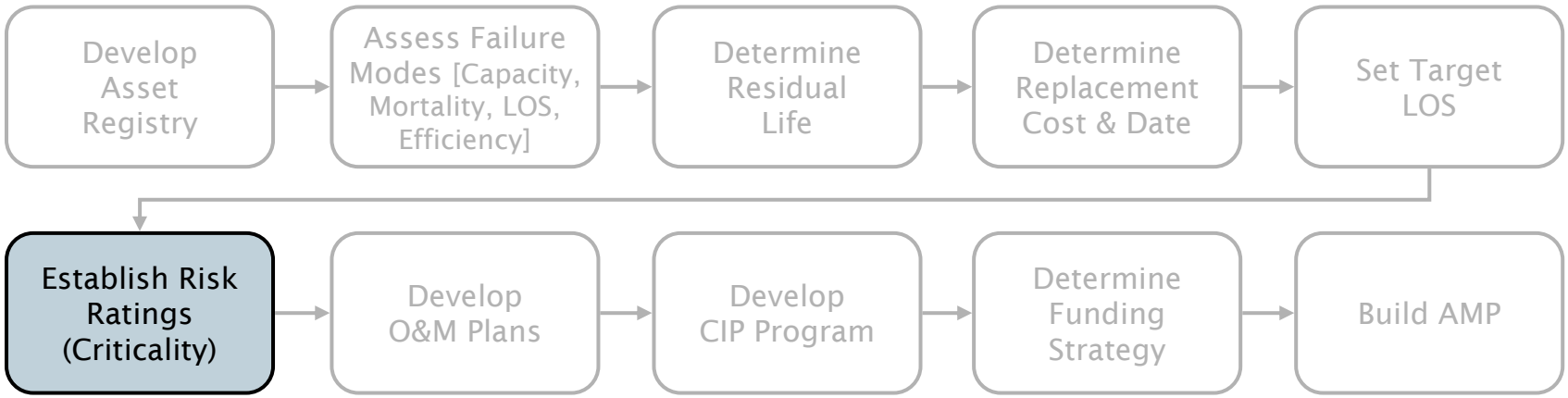
Years to 100% Probability of Failure	3 years
Redundancy	50% Backup
Probability	18.00%

Total BRE **1290**

Example of BRE level 3



Modifying the 10-step process



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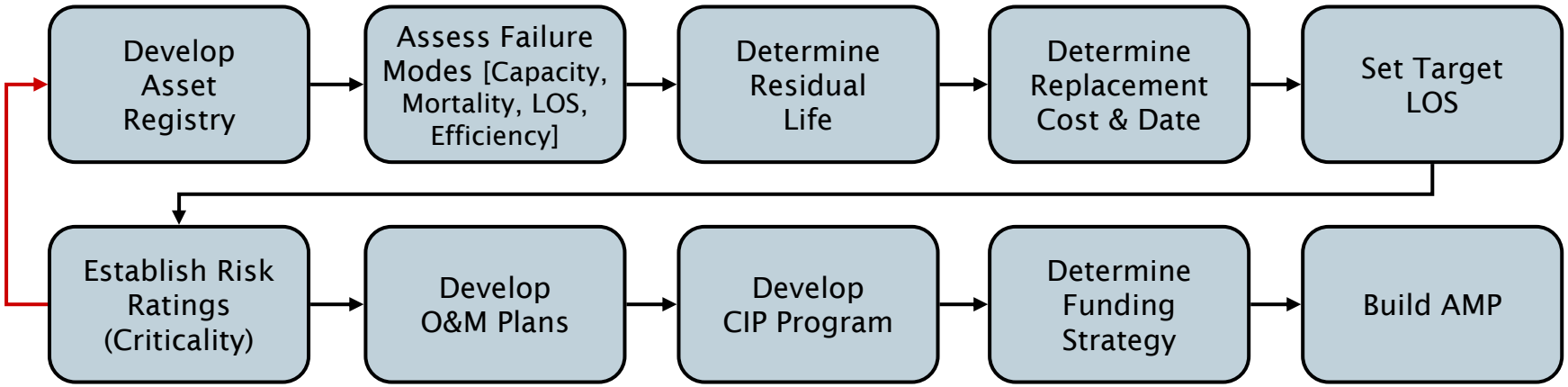
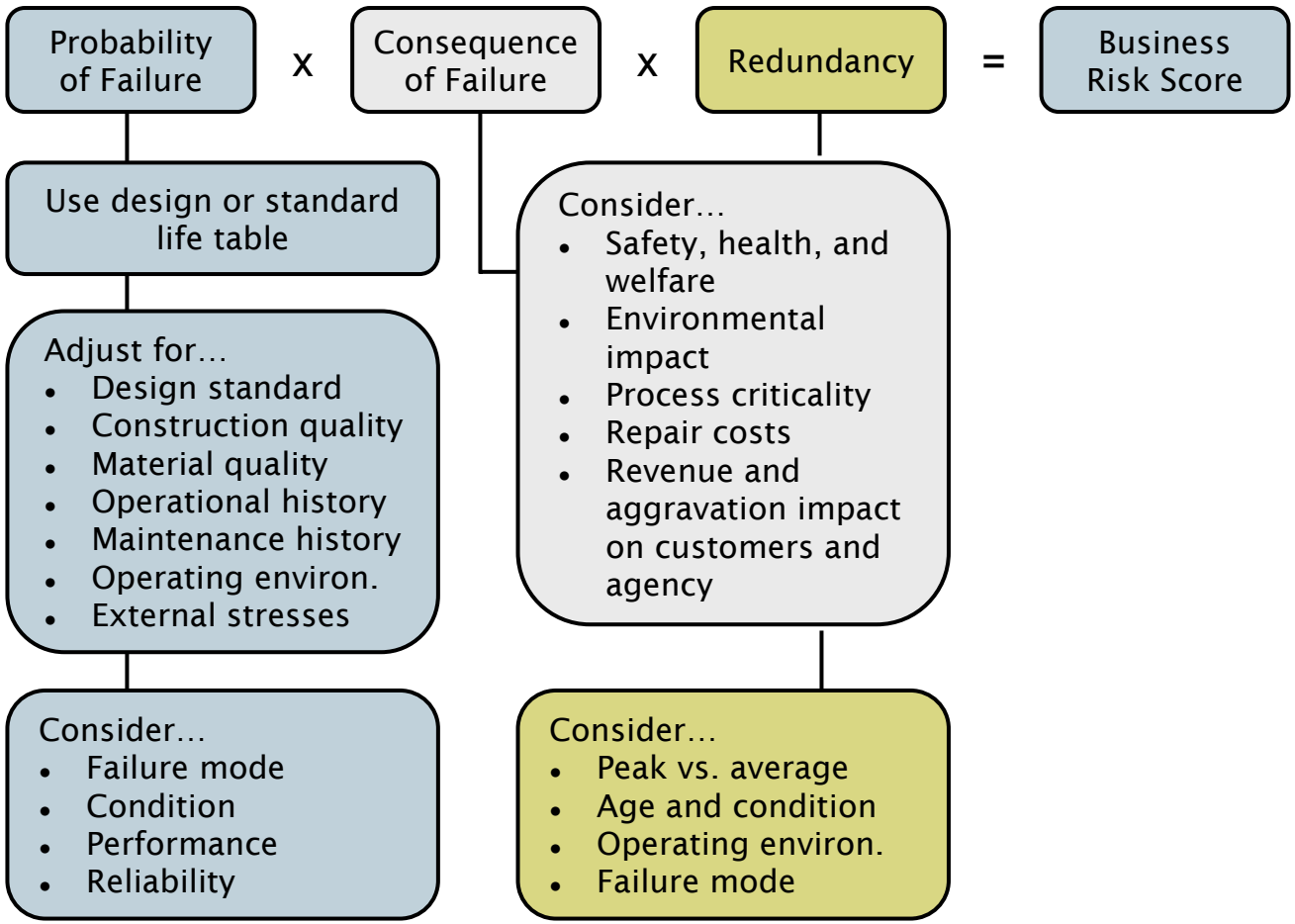
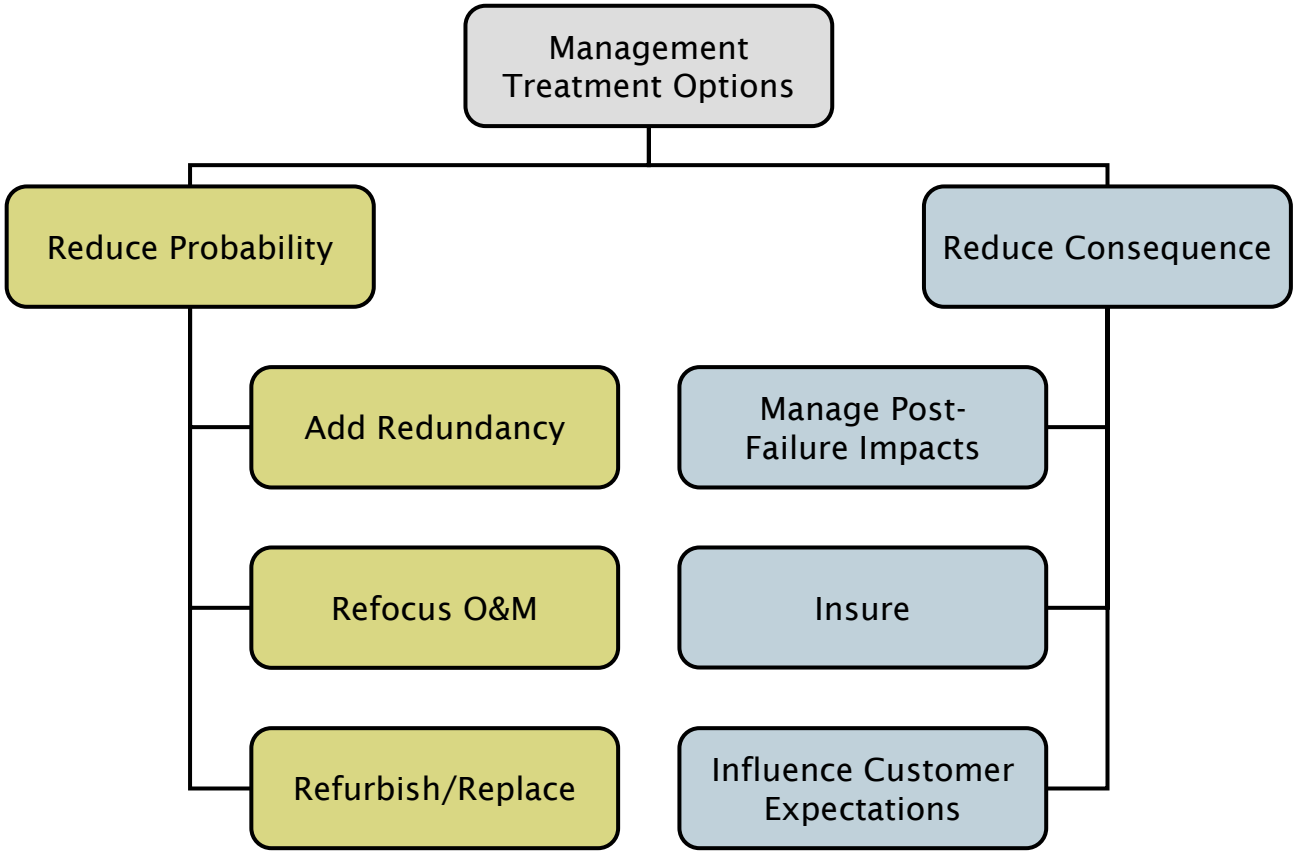


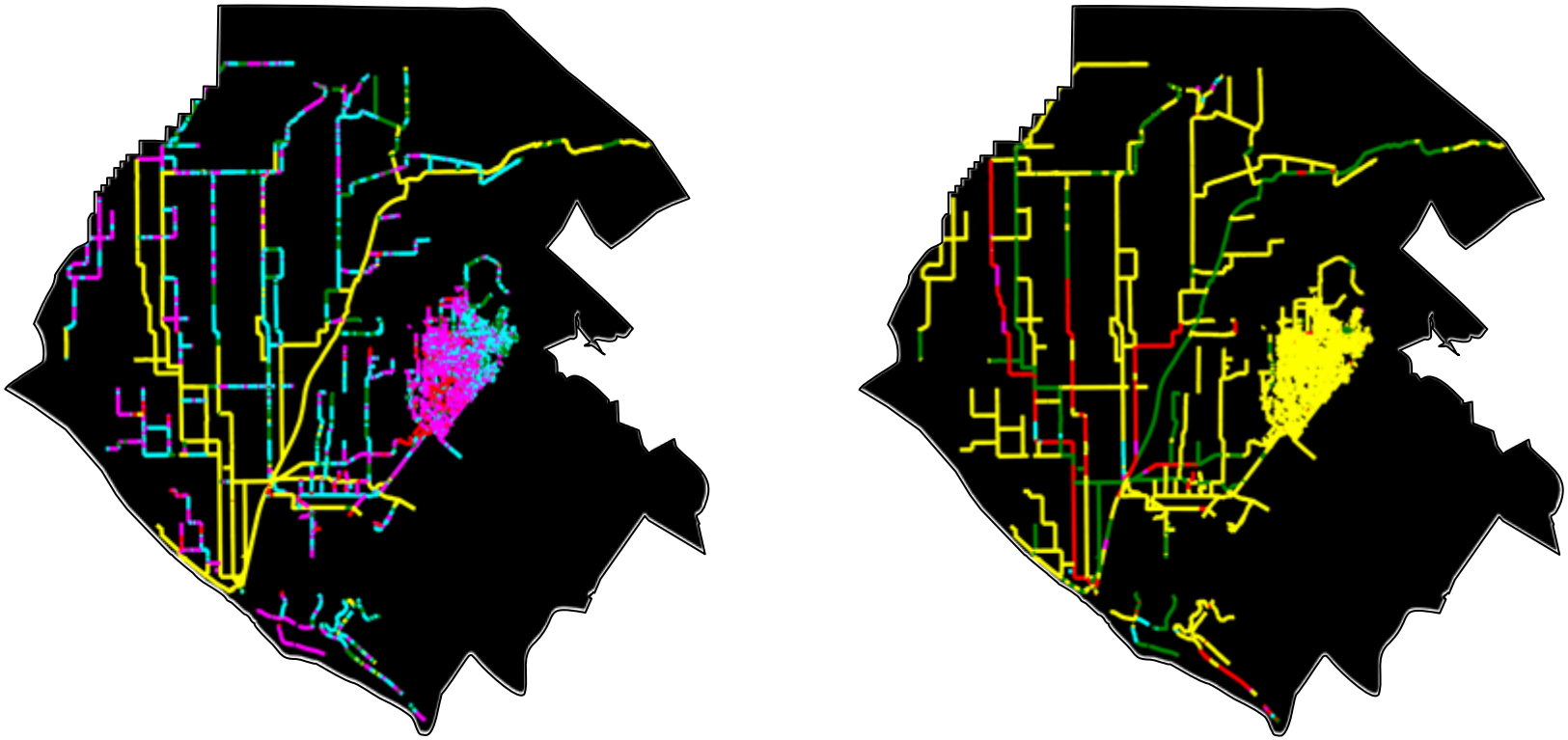
Putting it all together—calculating business risk



Managing risk—reduction options



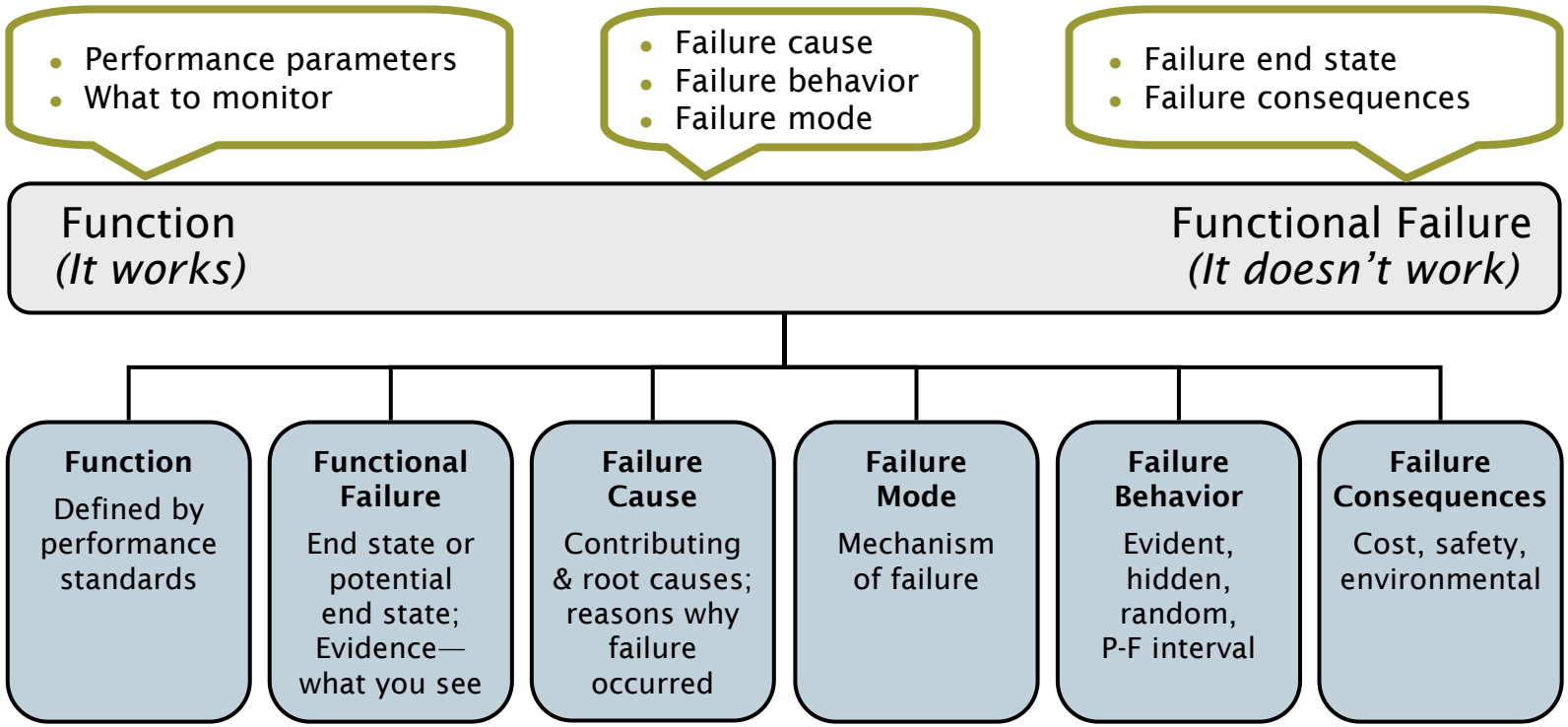
Risk Mapping



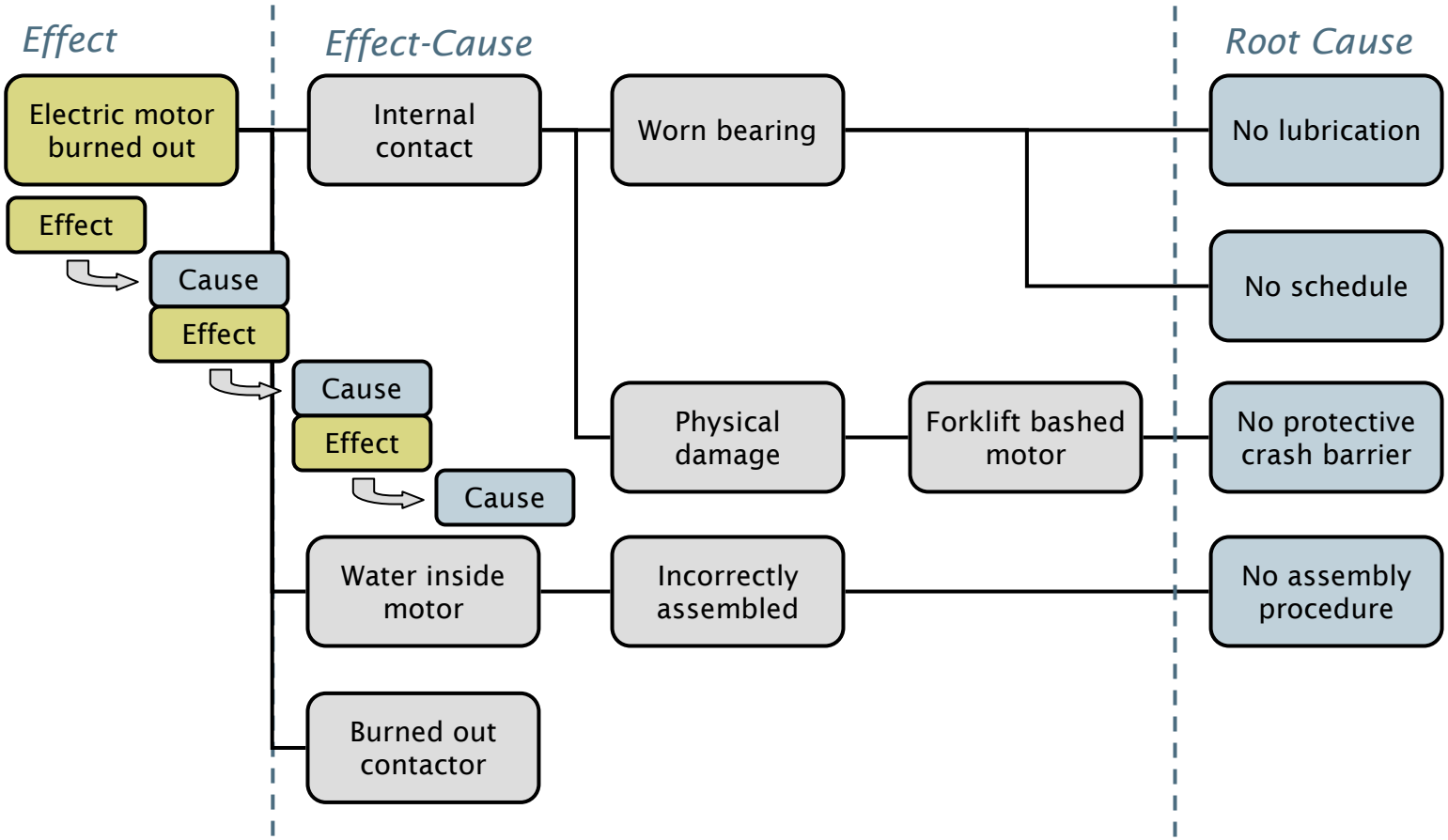
What caused the Jones Street power station to fail?

- Truck hits pole and causes power failure
- Don’t really know

Let's apply failure analysis techniques with Tom



Recall the cause and effect diagram



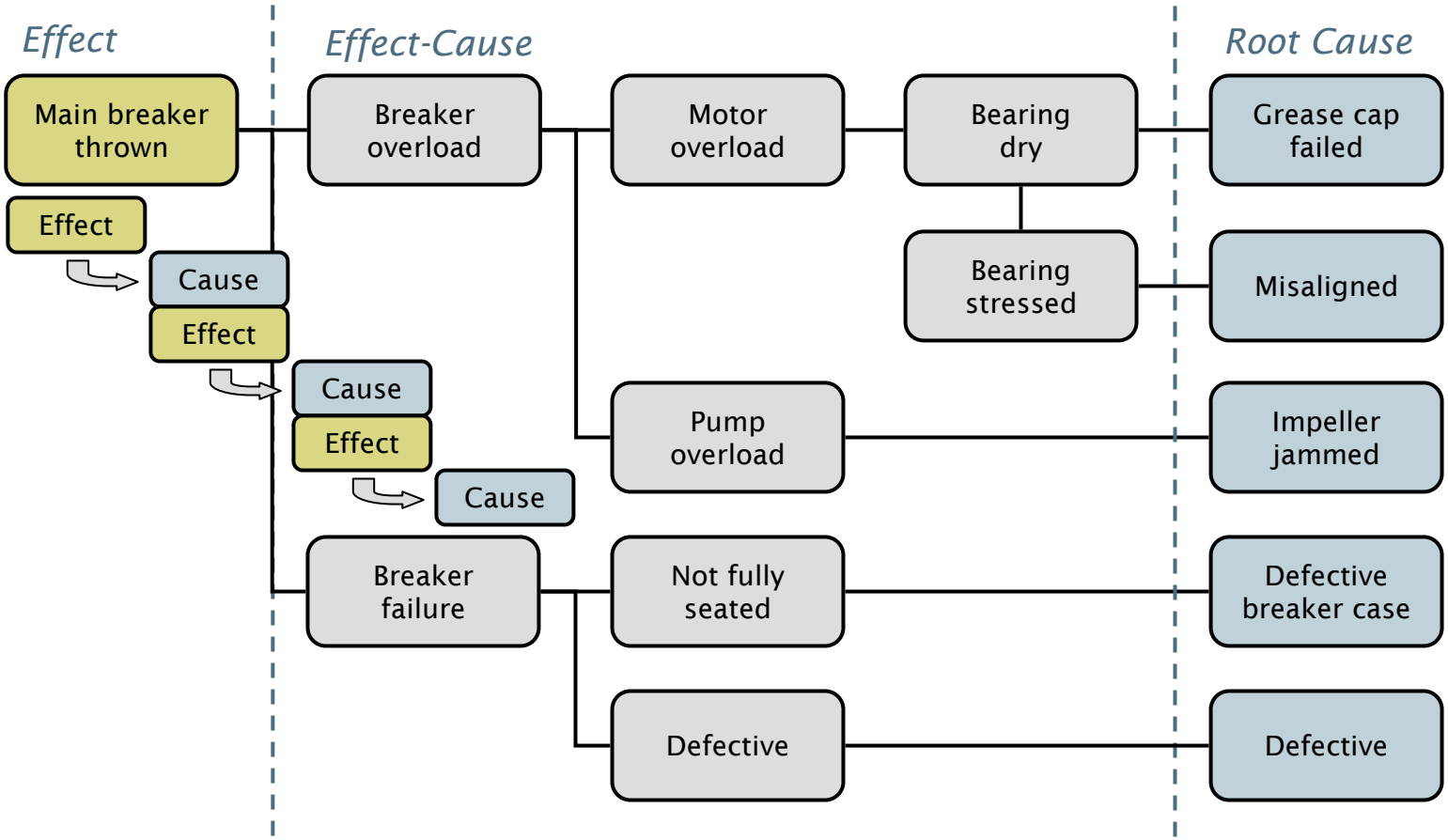
June's incident report notes

Hour	*Notes*
19:35	Entered superstructure to shut off power breakers before power-up. The main breaker had been thrown. No immediate clue as to what caused it to trigger. No sign of arcing or flash explosion around the box. That means neither Motor-pump 1 or Motor-pump 2 could run. No wonder the overflow. Why both down?
20:25	Power temporarily restored by Costly Electric & Illumination. Will return in am to install permanent pole. (Shouldn't we ask them to move it back from the road?)
20:30	Mac and I turned on main breaker to Motor 1. Immediately heard loud screeching. Seems to be from Motor 1. Immediately shut main down. Turned off breaker to Motor 1. Turned on main. Good news—Motor 2 ran fine. No unusual noise. Nice to have lights. Wonder if coffee pot works!
20:40	Noted that motor mounts on Motor 1 appear loose—black skid marks up to half inch from front feet. Back shows movement, but not as bad.

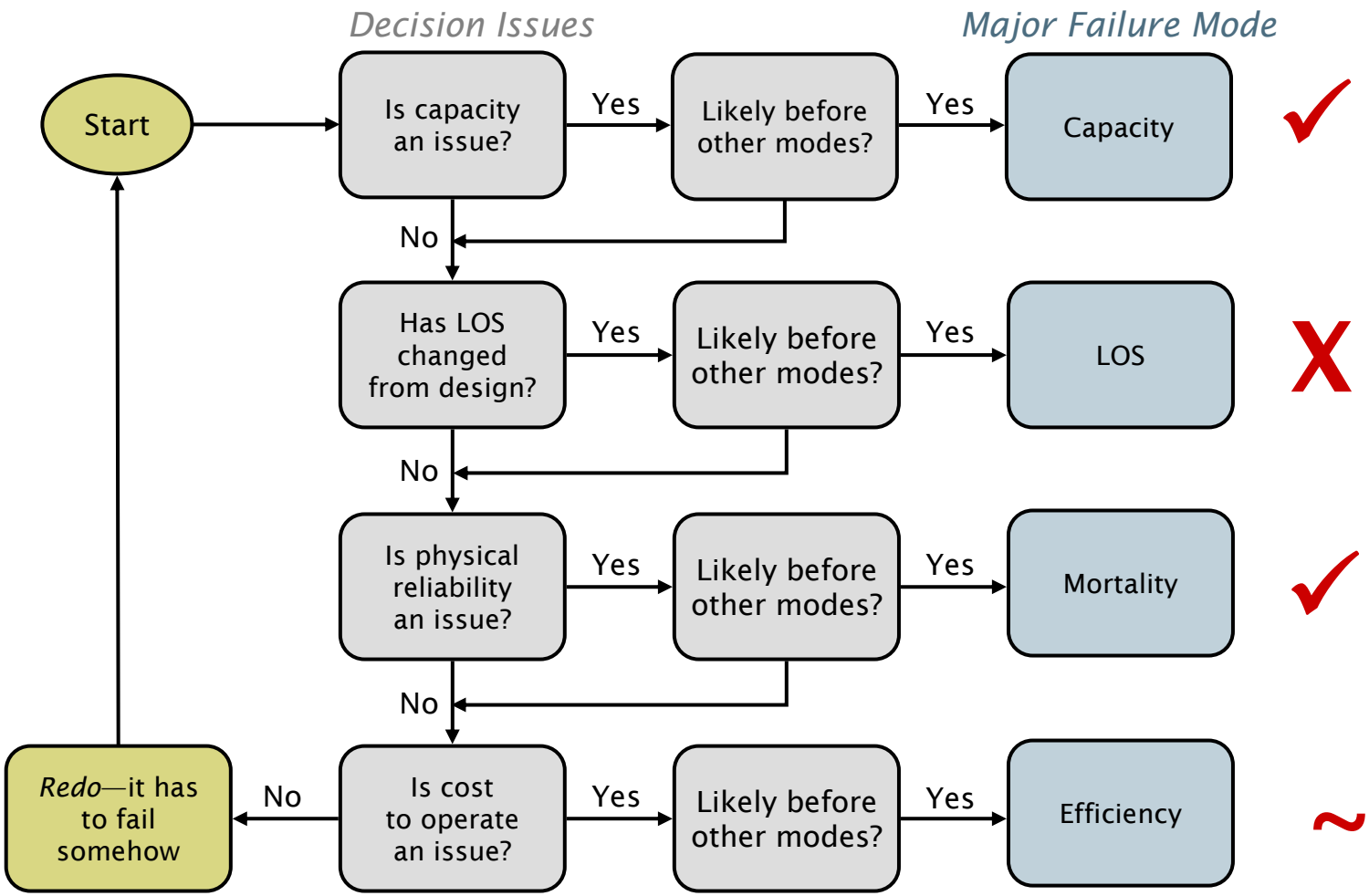
June's incident report notes, continued

Hour	*Notes*
20:45	I entered wet well and dry well with Motor 2 running. Mac stayed top. Noted that the two shaft guides on the wall for Motor-pump 1 was completely loose, one side pulled off wall. Bolts pulled clear from wall too. Noticed substantial play in pump shaft at the coupler to the shaft. Way too much play here. See photos.
05:15	My guess at this point—looks like vibration worked the shaft guides loose, increasing strain on the motor, working the motor loose, which strained bearings to point of break down.
05:30	Sent crews home with Motor-pump 2 running alone. What to do with Motor-pump 1? Repair? Refurbish? Replace? Will discuss with you after I get some shut eye.

Tom's cause and effect diagram



Which major failure modes are at work?



Strategic business risk

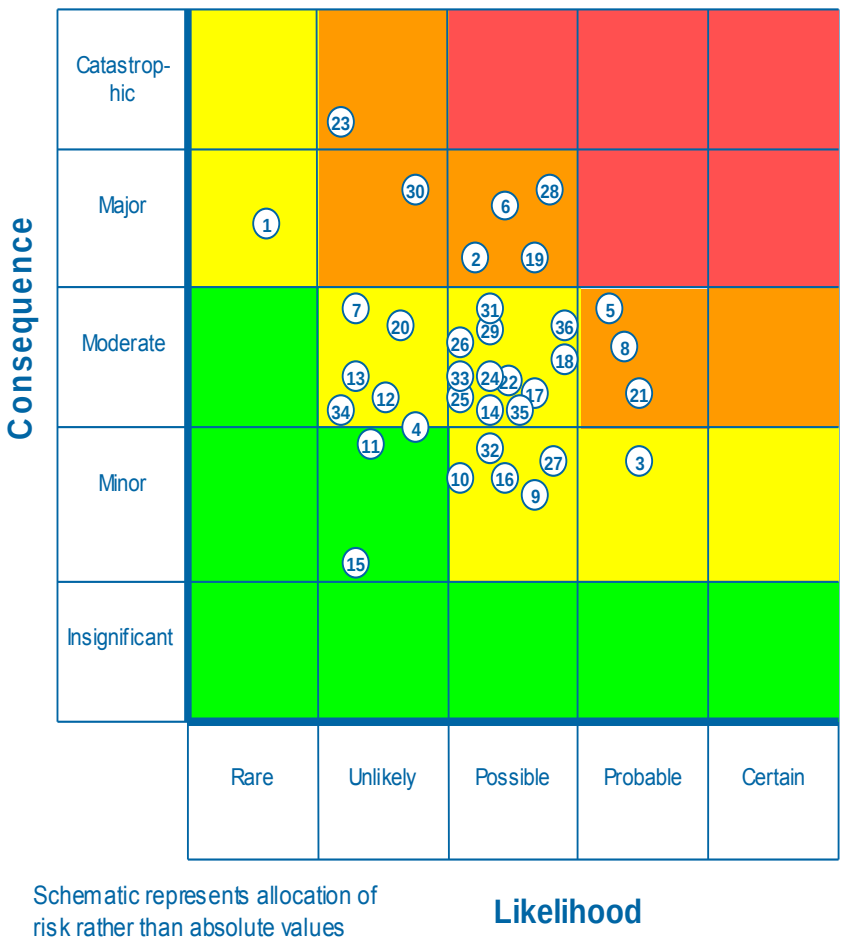
A *business risk* is the threat that an event—*action or inaction*—will adversely affect an organization's ability to achieve its business objectives and execute its strategies successfully.

Management of these risks has the twofold advantage of both *avoiding* and *minimizing* the risk itself, and *enabling informed business decision-making* based on an understanding of where the business vulnerabilities lie.

Mapping organizational risk: List risk elements

1. Terrorist attack on OCSD asset (e.g. treatment plant)
2. Regional power outage (up to 24 hours)
3. Safety incident on OCSD project
4. Internal security breach of IT systems
5. Increase in regulatory requirements
6. Finding places to put our biosolids
7. Potential loss of property tax revenue
8. Internal labor unrest at OCSD
9. Consultants ability to meet stakeholders expectations
10. Level of service change for environmental stewardship (constituents of concern)
11. Loss of public confidence in OCSD ability to perform core services
12. Exceedance of pollutants of concerns in groundwater related to GWRS
13. Internal business fraud (e.g. malfeasance)
14. Non compliance by OCSD that result in fines by regulators and legal activities by NGO's
15. Lack of incentives for early retirement of ageing staff that perform physical activities
16. Poor two way communications across OCSD levels
17. Lack of a leadership model in EMT and management level
18. Changing technology vs. CIP decisions
19. Board not supporting the funding required to support CIP/O&M (Full Cost Pricing)
20. Ability to accurately forecast growth of county
21. Loss of Board institutional knowledge
22. Not sustaining effective plant operations during construction
23. Disasters that destroy collection system or plant
24. Inability to appropriately fund staff at required technical strength
25. Inability to balance strategic initiatives that support GWRS (Groundwater Replenishment System) with plant operations
26. Emergency (operations level) communication among response teams and management for emergencies
27. Lack of alignment of organizational structure with requirements for strategic initiatives
28. Unable to put into effect funding agreement for SARI (Santa Ana River Interceptor)
29. Unable to negotiate new operating agreement with SAWPA (Santa Ana Watershed Project Authority)
30. Public ceases support for GWRS after investment is in place
31. Inability to meet new air emission standards for generating facility
32. Inability to balance impacts on neighbors with desire by public to reduce cost
33. Cost to meet odor and air emissions standards from facilities
34. Privatization of OCSD
35. Recruiting and retention of staff in face of local cost of living
36. Lack of succession planning at OCSD

Mapping organizational risk: BRE map



Critical Risks: None categorized as Critical

High Risks:

2 Regional power outage (up to 24 hours)
5 Increase in regulatory requirements
6 Finding places to put our biosolids
8 Internal labor unrest
9 Consultants ability to meet stakeholders expectations
19 Board not supporting the funding required to support CIP/O&M (Full Cost Pricing)
21 Loss of Board institutional knowledge
23 Disasters that destroy collection system or plant
28 Unable to put into effective funding agreement with key customer
30 Public ceases support for potable water after investment is in place

Medium Risks:

1 Terrorist attack on assetS (e.g. treatment plant)
3 Safety incident on major projects
7 Potential loss of property tax revenue
10 Level of service change for environmental stewardship (constituents of concern)
12 Exceedance of pollutants of concerns in groundwater
13 Internal business fraud (e.g. malfeasance)
14 Non compliance that result in fines by regulators and legal activities by NGO's
16 Poor two way communications across department levels
17 Lack of a leadership model in EMT and management level
18 Changing technology vs. CIP decisions
20 Ability to accurately forecast growth of county
22 Not sustaining effective plant operations during construction
24 Inability to appropriately fund staff at required technical strength
25 Inability to balance strategic initiatives that support groundwater replenishment with plant operations
26 Emergency (operations level) communication among response teams and management for emergencies
27 Lack of alignment of organizational structure with requirements for strategic initiatives
29 Unable to negotiate new operating agreement with key customers
31 Inability to meet new air emission standards
32 Inability to balance impacts on neighbors with desire by public to reduce cost
33 Cost to meet odor and air emissions standards from facilities
34 Privatization of organisation
35 Recruiting and retention of staff in face of local cost of living
36 Lack of succession planning

Low Risks:

4 Internal security breach of IT systems
11 Loss of public confidence in organisation to perform core services
15 Lack of incentives for early retirement of ageing staff that perform physical activities

Risk register

Risk Identification and Analysis							
#	Risk Issue	Causes and Notes	Potential Impact / Consequence	Current Mitigation Measures	Initial Risk		
					Consequence	Likelihood	Risk
6	Finding places to put our biosolids	Potential ordinances against OCDD disposal of biosolids. Lack of availability of suitable disposal sites. Lack of on site disposal. Natural closure of transport routes. Saturation of market with biosolids.	Public health implications. Increased costs to source landfill sites. Limitations for onsite storage at OCDD. Violation of permit.	OCDD Bias lerplan which covers on and off site actions. Specific section addressing monitoring the situation including regulations, politics etc. Existing multiyear contracts with different vendors. OCDD actively seeking new tactical options (e.g. composting). Active promotion in county uses of solids. Program inplace to seek and setup new technologies to identify alternatives for biosolids disposal.	Moderate	Possible	Medium
7	Potential loss of property tax revenue	Political decision regarding funding made at State level. State budget issues. Perception of self sufficiency at OCDD. Current revenue $ 100m per year from property tax.	Need to increase rates. Reduction in capital investment. Operating budget reduction.	New state legislation structure that makes changes (reductions) more difficult.	Major	Possible	High
8	Internal labor unrest at OCDD	Link to risk 4. Union demands. Completion of contract.	Work to rule. Staff shortages. Level of service impacted. Vandalism. Morale. Negative impact on recruitment. Interruption to supply of chemicals (storage under a week).	Labor contracts are negotiated and OCDD offers a competitive salary and benefits program. Turnover of staff currently at 3% per year. Labor management committee reviews organizational issues, collaborative issues/problem solving. Contract negotiations, covering 90% of staff, begin in 3rd quarter 2006 and will be completed by end of second quarter June 2007.	Moderate	Unlikely	Medium

Key points from this session

Given my system, which assets are critical to sustained performance?

Key Points:

- Not all assets fail the same way
- Not all assets have the same likelihood of failure
- Not all assets have the same consequence of failure
- Understanding failure drives acquisition, maintenance and renewal management decisions.

Associated Techniques:

- Failure analysis ("root cause" analysis; failure mode, effects and criticality analysis; reliability-centered analysis)
- Failure codes
- Probability of failure
- Consequence of failure
- Business risk exposure
- Asset list by business risk exposure level
- Asset functionality statements

Tom's spreadsheet